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Measuring cross border mobility between Estonia and Finland with Mobile Positioning Datasets

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Summary

The paper provides a statistical overview of people's cross border commuting between Estonia and Finland based on passive mobile positioning data. Studying movement of mobile phones between mobile networks enables making generalisations on the flow of people between the countries. The privacy of individuals is strictly protected according to the European Union data protection regulations. The paper also explores existing problems of measuring labour commuting between the two countries, and discusses the methodological and legal aspects of using mobile positioning data for the measurement of mobility and commuting.

The paper is presented for discussion to the Conference of European Statisticians seminar on migration statistics.



I. Introduction

1. The rapid increase in the spatial mobility of people is a phenomenon of the 21st century (Sheller & Urry 2006). People have become more mobile because borders have opened, tourism has become a part of lifestyles and the labor market has changed. Transnational lifestyle, living and working in different countries, has spread quickly all over the world (Massey et al 1994). The mobility of society is also significantly influenced by the development of information and communication technology (Kellerman 2013). Studying this mobile society is more complex than ever before. In a world with open borders, it is more difficult to obtain border crossing information, and transnational jobs are often connected to illegal tax schemes (Tyldum & Brunovskis, 2005). An important problem hindering the gathering of mobility statistics is, however, the fact that people commuting between two countries and places of residence often do not know themselves where they would like to live and what their perspective for the future is (Zaiceva & Zimmermann, 2008; Levitt & Jaworsky, 2007). Due to this, the lives and work schedules of cross-border commuters are unclear and they are not able to provide sufficient information about their statuses during the course of censuses and interviews.

2. One example of transnational lifestyle can be found at the Estonian-Finnish border. The mobility between these two neighbouring countries is heavy because of tourism, businesses and labour commuting. Because of open borders and the illegal labour market it is hard to control or to gather statistics about cross border mobility.

3. Labour mobility is largely caused by differences in wages between countries. These differences may be formed as a result of discrepancies between the supply and demand of labour (Russell 1995). As wages in Finland are significantly higher than in Estonia, labour mobility between Estonia and Finland is remarkable and requires more research. There is need for new data sources for compiling statistics. These are needed for developing policy measures on cross border commuting. Traditional methods are not effective in describing the diversity of cross border mobility practices (Ahas 2012).

4. Estonia and Finland are using anonymous passive mobile positioning data in order to study spatio-temporal mobility between the two countries (Ahas et al. 2008; Ratti et al. 2010; Young et al 2012). The study of movement of mobile phones between mobile networks enables estimating the flow of people between countries and regions. The privacy of individuals is strictly protected according to European Union (EU) data protection regulations. The statistical offices follow the requirements specified in EU directives on processing personal data (Directive 95/46/EC) and on the protection of privacy in the electronic communications sector (Directive 2002/58/EC). Furthermore, the Estonian Data Protection Inspectorate has evaluated the related data collection practices.

II. Data and available results

A. Passive mobile positioning data

5. Passive mobile positioning data are generated as a part of Mobile Network Operator's (MNO) operations and are automatically recorded in log files as secondary data of phone use. The most commonly available are Call Detail Records (CDR) and Data Detail Records (DDR). Different operating systems (Ericsson, Nokia-Siemens, Motorola etc.) have different technical solutions and terminology for such data outlets, but most operating systems have a similar structure (Dahlman et al, 2011; Smoreda et al. 2013).

6. The advantages of CDR data over traditional methods used to measure border crossing statistics, such as censuses, surveys and counters, are the better spatial and temporal resolution of data, a longer observation period, and automatic digital data collection. In EU, MNOs have to comply with the EU Directive 2006/24/EC for data retention.

7. In this study, we used CDR data from the memory files of the biggest Estonian mobile operator, EMT, who holds a market share of 40–45% in Estonia. The statistical offices make use of data about the use of Finnish telephones (roaming) in the EMT network for incoming visits and the use of EMT phones in Finland for outgoing visits. The management of data and the segmentation of visitors according to space-time flows is handled by Positium LBS, who used the special software Positium Data Mediator (Positium 2013). For Estonian phones abroad, data on age groups and gender from the operator's database is used and the home anchor point in Estonia is calculated using an anchor point model (Ahas et al. 2010). Because of data protection and privacy regulations, it is not possible to position phones as precisely in Finland.

8. CDR location information is initially stored as Cell Global Identity (CGI) which has a unique identity and location for each antenna. Spatially, CGI is the area of the antenna mobile radio coverage, which in reality is not physically fixed. Typically, the Global System for Mobile Communications (GSM) network's maximum theoretical signal area of a cell is 35 km, but cell antennas located along coastal areas are often further amplified to provide the best possible radio coverage across the sea. All these characteristics of passive positioning data need to be considered when using such data for migration statistics.

B. Database used in empirical study

9. Databases of call activities in the EMT network were analysed for years 2009, 2010 and 2011. This included call activities made by Estonian phones in Finland, and call activities made by Finnish phones in Estonia. Call activity is any active use (incoming or outgoing; voice, text, internet, services) of a mobile phone. The database used for the study consists of call activities (time, location) of random identifies (IDs) (Table 1). The country of origin or nationality of visitors is determined on the basis of the registration country of the mobile phone. Thus, a phone registered in Estonia may be used by a person of any nationality. Still, the registration of a mobile phone shows the place where the person is spending most of their time or has strong connections with. Random IDs are not identifiable, but certain phone numbers are given the same ID during a trip to another country by the operator. Because of privacy protection requirements we worked with an aggregated dataset, thus it was not possible to study individual entries or ID-s.

Table 1.

Data recorded on the call activity used in the study.

Phone user	ID	Time	Location
Finnish (roaming) phone in Estonia	Country; Random ID	ss:mm:hh dd:mm.yy	Network cells
Estonian phones (roaming) in Finland	Random ID	ss:mm:hh dd:mm.yy	Country

C. Visitor segments

10. Based on this CDR data various statistics are generated from roaming logs to mobility description: number of visitors, number of visits, number of days, and number of

nights. In the following section we describe the following statistics (Silm & Ahas, 2012; Järvi et al 2014).

(a) Visitor – unique person (mobile phone user, ID) who is travelling to another country and has engaged in call activities while abroad;

(b) Visit – unique visit to another country by a person. One visit is normally composed of two trips: one into destination and second back home from the destination. One person can make multiple visits. Visits, which are made directly from Estonia to Finland in the case of Estonians, and directly from Finland to Estonia in the case of Finns, without transit or stopping in a third country are included in the estimation;

(c) Trip – unique one way trip to another country by a person, for example trip from Estonia to Finland; or trip from Finland to Estonia;

(d) Number of days – duration of each visit in days;

(e) Number of nights – duration of each visit in nights. The formula for calculating the number of nights in one visit is: nights = days – 1.

11. Different segments of visits/visitors based on visit duration, number of visits per year and number of days spent in another country per year are identified.

1. Visits

12. Visits are divided on the basis of the length of stay:

- Transit visits – visits to another country (Finland/Estonia) for a short period (may be <3...<12 hours) and leaving to a third country on the same day.
- Visits to the destination divided on the basis of number of visited days: one day visits, 2–4 day visits, 5 or more day visits.

2. Visitors

13. Based on the total number of days spent in the other country, visitors are divided into:

- 1 day visitors
- 2–30 day visitors
- 31+ day visitors
- 183+ day visitors. According to the common definition (WTO), a visitor who is staying in other country for 183 days or more is considered a foreign labourer.

14. Visitors are further divided on the basis of the number of visits to another country into:

- one time visitors
- 2–4 time visitors
- 5 or more time visitors.

D. Results

15. The advantage of passive mobile positioning is that it creates the opportunity to analyse foreign visits of a large part of the population over a long period of time. It allows exploring the distribution of trips by the frequency or duration of visits. The duration of trips can, in turn, be calculated in terms of one trip or year or study period. The

segmentation process can also include information on the timing and geography of trips. The main results of these distributions show that there are more persons making short trips from Finland to Estonia. There are fewer people travelling from Estonia to Finland, but the total duration of their stay in Finland is much longer.

E. Duration of trips

16. Statistics on the duration of trips in the two directions (from Finland to Estonia and from Estonia to Finland) differ greatly. Only the volume of transit trips and short-term (1–9 days) trips are comparable and demonstrate the importance of short-term visits (probably for tourism and business) in travel between the two countries. The distribution of trips lasting over 10 days shows the share of commuting for employment purposes, which is what interests policy makers: 13.4% (180,487 trips) of trips from Estonia to Finland last 10+ days. Most probably this includes persons who work in Finland, but definitely Finns who have taken up residence in Estonia as well. The share of trips from Finland to Estonia which last 10 days or more is only 2.5% (57,564 trips). The number of Estonians who spend 183 days or more (defined by WTO as foreign workers) in Finland is 13,652 (4% of total visitors). In total, 1,155 Finns stayed in Estonia for more than 183 days, which amounts to just 0.1% of visitors. It is very likely that the majority of these people from both countries work or have family relations in the neighbouring country.

Table 2.

Visits made between Estonia and Finland by duration, annual average for 2009–2011

<i>Duration of visits</i>	<i>Estonians to Finland</i>		<i>Finns to Estonia</i>	
	<i>Number of visits</i>	<i>%</i>	<i>Number of visits</i>	<i>%</i>
Transit	156 576	11.6	188 894	8.1
1 day	368 798	27.4	995 209	42.7
2 days	243 663	18.1	547 710	23.5
3 days	126 207	9.4	249 178	10.7
4 days	88 676	6.6	118 419	5.1
5 days	63 911	4.7	63 665	2.7
6 days	41 389	3.1	38 669	1.7
7 days	28 689	2.1	34 649	1.5
8 days	25 544	1.9	24 530	1.1
9 days	23 235	1.7	12 997	0.6
10+ days	180 487	13.4	57 564	2.5
Total	1 347 176	100	2 331 483	100.0

F. Frequency of trips

17. The annual frequency of trips per person (ID) also confirms that for the majority of visitors in both directions it is customary to make one or two trips per year (Table 3). Naturally, Finns dominate in making one-day trips: 72.2% of them go on one-day trips, whereas the share is only 49.9% for Estonians. Until up to 9 trips per year, the distribution of the frequency of trips is rather even between visitors of the two countries. In terms of determining labour migration, the focus is on people with 10 or more trips per year. Here, the share of persons who “often” travel from Estonia to Finland clearly stands out,

amounting to 10.6 % or 34,767 persons of the total number of travellers. The share of persons who travel "a lot" from Finland to Estonia is only 0.8% of the total number of travellers, i.e. 12,343 persons. Therefore, attention should be paid to people who work abroad particularly among persons who go to Finland 10 and more times per year. Where exactly the threshold should be set, depends on geographic distance and several other factors. Interviews and a phone use survey should probably be organised to help to fine-tune the methodology.

Table 3.

Visits made between Estonia and Finland by frequency of trips, annual average for 2009-2011

<i>Frequency of visits</i>	<i>From Estonia to Finland</i>		<i>From Finland to Estonia</i>	
	<i>Number of visitors</i>	<i>%</i>	<i>Number of visitors</i>	<i>%</i>
1	164 093	49.9	1 150 877	72.2
2	58 789	17.9	265 630	16.7
3	27 190	8.3	86 411	5.4
4	15 052	4.6	35 460	2.2
5	9 558	2.9	18 124	1.1
6	6 680	2.0	10 784	0.7
7	5 104	1.6	6 909	0.4
8	4 163	1.3	4 741	0.3
9	3 570	1.1	3 488	0.2
10+	34 767	10.6	12 343	0.8
Total	328 966	100	1 594 766	100.0

III. Temporary labour in Finland – Available data and limitations

A. Estonian sources and data limitations on temporary foreign labour in Estonia

18. Statistics Estonia can use two main sources to estimate the number and profile of those who are commuting for the purpose of work. First, population and housing census data offers sufficient data to estimate both the number of persons who were working abroad during a certain period (final weeks in 2011) as well as their personal characteristics. The disadvantage of this source is that it only gives information about 2011 and does not offer a continuous time series. The time series can be acquired from the Estonian labour force survey (LFS) but its main problem is the lack of sufficient respondents to describe more contrasted profiles. There would also be a problem of underestimating the number of those working abroad since it is difficult to reach them. Estimations based on the Estonian LFS can be used as a reference to the 2011 population and housing census; according to the survey the total number of people working abroad in the 1st quarter was 24,800. According to the 2011 population and housing census, the number of people working abroad was nearly 25,000. The number of people who worked in Finland was more than 15,000

according to the 2011 population and housing census, and the LFS showed similar results in the 4th quarter of 2011, in total 15,900 persons.

B. Data limitations for statistics on temporary foreign labour in Finland

19. Immigration to Finland has increased steadily and markedly since 1990's. As the volumes of immigration have increased, so has the need for information on a variety of issues related to immigration.

20. Statistical information on labour-based immigration is of particular interest for several administrative fields. Information on labour-based immigration is noticeably called for in formulating and monitoring policies and measures in economic and employment administration, in regional development, and in countering the black economy. However, statistics on labour-based immigration currently face severe limitations. Most importantly, official labour market and employment statistics are based only on population residing permanently in Finland.

21. For instance, Statistics Finland's annual register-based employment statistics, while yielding information on population's economic activity and employment, are based on permanent resident population. Those residing in Finland less than 12 months, or foreign nationals whose residence is attributed as temporary, regardless of the length of their stay, are not included in Statistics Finland's employment statistics.

22. Statistics Finland's LFS collects data on employment and unemployment. This data is based on a random sample, drawn twice a year from the Statistics Finland population database. The monthly sample consists of about 12,000 persons and data are collected with computer-assisted telephone interviews. Due to the nature of its sample construction, this survey does not reach those residing in Finland temporarily. In addition, since the data are collected via telephone interviews and due to possible language barriers, even permanently residing foreign nationals are at risk of being omitted from and under-represented in the LFS.

23. Statistics Finland's structural statistics on wages and salaries describe the numbers, hourly and monthly earnings, and the formation and distribution of employees' wages and salaries. The data derived from Statistics Finland's data on wages and salaries and is formed by combining data collected by employer organisations from their members with those from Statistics Finland's wage and salary inquiries for unorganised employers.

24. Structural statistics cover all public sector employees, but private enterprises employing less than five employees are not included in the data. In addition, agricultural (as well as forestry and fishery) enterprises are excluded from structural statistics. Due to these restrictions in data collection, Structural statistics leave out a cluster of small scale enterprises, many of which are run by self-employed immigrants, as well as enterprises in agriculture that typically rely on seasonal labour to a considerable extent.

25. The demand for information about temporary foreign labour is vast, and government agencies, in particular, have requested such data persistently. For instance, in 2004, the Finnish Parliament, while passing the directive on the right of citizens of the European Union to move and reside freely within the Member States, called for monitoring the effects of free movement on labour market. However, the revision and initiation of much legislation continuously requests reliable and accurate statistical data about temporary foreign labour.

26. The Programme for the Finnish Government 2011 establishes a definite objective to clarify and improve statistics and research activities concerning immigration. In its audit report *Työperäinen maahanmuutto* ("Labour- Based Immigration"), the National Auditing

Office notes that there are severe deficiencies in the availability and usability of statistics regarding temporary foreign labour, particularly from European Union member states.

27. The biggest obstacle for procuring statistics on temporary immigrant labour is the fact that foreign nationals do not acquire, for the most part, a Finnish social security number, which is imperative for register-based statistics production. The Finnish Aliens' Act is currently under revision and might eventually bring changes that will enable more fluent and comprehensive registering and, thus, produce statistics on temporary foreign labour. Proposed revisions to the Aliens' Act entail, for one, assigning a Finnish social security number to third country immigrants when they are issued a residence permit. Secondly, while the authority to assign social security number has earlier been restricted to magistrate offices, and more recently, to Office of Tax Administration, the revised Act would give the local police the right to assign social security numbers to EU-nationals after a three-month period of residence.

28. These revisions would expand the scope of foreign workers possessing a Finnish social security number and would therefore contribute to more consistent and reliable register-based statistics production. However, EU-residents staying in Finland less than three months would, even under the revised Act, remain unregistered and thus be without social security numbers. Further still, many EU-residents refrain from registration regardless, and many are not even aware that such an obligation exists in the first place.

29. Another profound deficiency is the fact that, currently, no government agency bears responsibility for statistics on labour-based immigration. In addition, while several agencies collect information about immigrants and immigration, no strategy to coalesce information from various registers and databases exists.

30. To respond to the need for and deficiencies in labour-based immigration statistics production, Statistics Finland has, from the initiation of the Ministry of Finance, set up a working group to investigate current limitations and deficiencies in registers, data, and statistics of labour-based immigration. The objective of the working group is to determine prerequisites for efficient and comprehensive statistics production of temporary immigrant labour, and consequently, present an action plan to meet these essentials.

31. Improving the registration processes of foreign workers, and developing processes to channel information about temporary foreign workers from enterprises to government agencies, are pressing needs. However, such measures aim to profoundly improve production of statistics on temporary foreign labour and can be lengthy processes. Therefore, prompt solutions for procuring data on labour-based immigration are in urgent need.

32. Increasing flows of commuting between Estonia and Finland is of particular interest for several policy-making authorities. However, free movement of labour within European Union territory sets definite limitations on data collecting of migrant labour, since border control mechanisms no longer yield data. Therefore, new and innovative approaches to data collecting must be developed.

IV. Discussion

A. Finnish perspective

33. Three main issues of concern were identified in relation to accessing mobile positioning data for the purpose of producing tourism statistics in Finland and these concerns will also potentially affect producing statistics about temporary labour migration.

34. First, the current Statistics Act obliges enterprises to provide data on their products and services but not on the clients consuming these products and services. Therefore, the current Statistics Act does not oblige MNOs to provide mobile positioning data to Statistics Finland.

35. Second, according to the Act on the Protection of Privacy in Electronic Communications identification data may only be processed by a natural person employed by or acting on behalf of a telecommunications operator.

36. Thirdly, the Office of Data Protection Ombudsman stated that the raw data, although anonymized, still constitutes personal data. The anonymization of data does not guarantee anonymity of the individual if the identifier individualising the subscriber connection is the same all the time, many observations are collected from the subscriber connection by means of location data and timestamps, and the time of data collection and the number of observations accumulated in this way are in no manner restricted. Thus, there arises a need for a mediator to process data into aggregated form on the premises of the operator. Such a mediator has to have access to the raw data maintained by the operator, as well as possess methodological competence and tools to process the raw data into aggregated data. This scenario involving a mediator is challenging technically, financially and in terms of organization.

37. As a conclusion there are two possible paths for Statistics Finland to gain access to the mobile positioning data:

(a) Voluntary basis: Operators process the data into aggregate form either themselves or by use of an intermediate party and deliver the aggregates to Statistics Finland.

(b) Legal basis: The Statistics Act should be updated to authorize Statistics Finland to obtain mobile positioning data from operators. In parallel, the Act on the Protection of Privacy in Electronic Communications should be updated to entitle the operators to provide data for Statistics Finland.

B. Can we trust the mobile data?

38. The data presented in this study is an alternative source for determining international mobility flows. Statistics are interesting and the data collection method is cost effective. Here we described only the first steps on developing such a segmented algorithm: a) duration of trips; b) frequencies of trips, in addition, we have done but not described here c) timing of trips; d) geographical origin and destination of trips. And the statistical offices discovered potential segments of travellers with mobile phones which are transnational commuters. They have different timing and duration of trips depending on occupation, season and economic situation in origin and destination.

39. Certainly these statistics also have problems: the total number of visitors was evaluated based on the market share of one large mobile operator. It must be emphasised that the study includes people that actively use their mobile phone while abroad, i.e., they have maintained an active connection with their homeland. Clearly there are many persons who use much cheaper local mobile phone service or do not use mobile phones at all while abroad. Nationality (country of origin) was determined by the country in which the phone is registered and usually people register their phones in a place with which they have a strong connection or where they stay longest. Certainly there is a need for a detailed phone use study in the future.

40. Using mobile positioning data in scientific research also has several shortcomings that we have to keep in mind when interpreting the results. One of the weaknesses of such quantitative statistical data is that we do not know the exact motivations behind the visits.

The most important question relates to sampling: Who are the persons who have phones? Are they using phones during travels? How often do visitors use phones in a foreign country? As roaming calls are expensive, it is likely that wealthy tourists and businessmen use their phones more often than less active people with a lower income (children, students, pensioners). This means that sampling issues are also related to lower income and age groups. Calling is also connected with cultural differences, such as calling regulations and traditions. Another problem that arises in the case of using mobile positioning data is its quantitative structure – there is information about the locations of calls (dots), but not on who is really making the calls, what kind of visit the person is on, and what kind of transportation he/she is using. The huge amount of quantitative data also poses a problem for data processing and cleaning; the databases are too large to enable using traditional software and data preparation options. From the positive side, getting mobile positioning data does not cause any extra burden and the production of the statistics can be done very fast. Given the limitation of traditional surveys and administrative register, a new alternative source that can give information about labour-based immigration is mobile positioning data. Mobile positioning data are a collection of information in a mobile operator's network on events that specify a specific subscriber's presence in time and space.

41. Estonia has been a leading country in the use of the mobile positioning data in various domains. This is because Estonia is one of the leading information technology (IT) countries with its e-government services and various public and private IT applications that create an environment that supports new technological development in many areas. Analyses based on mobile data in tourism, transportation and other public domains have been conducted by the University of Tartu, Positium and some other organisations already for several years.

42. It is clear that there are differences between the concepts used in the official statistics and what can be obtained from mobile positioning data. These discrepancies need to be taken into account when interpreting or comparing results. However, administrative data sources do not always measure what we want to measure, either. Assessment of accuracy, especially coverage issues, is very problematic for this data source because there are many components that contribute to the coverage bias and assessing all of them, separately or together, is a complex task and requires additional data sources. Some examples of coverage problems are: people not owning a mobile phone, people having many Subscriber Identity Module (SIM) cards, people changing their SIM to local SIM card when in other country, data available from selected MNOs only.

43. Passive mobile positioning data (the most likely data available from mobile network operators) contains data about events like making a call or sending a text message only. Due to the nature of passive mobile positioning data, the quality of the estimates based on this data source depend on changes in the telecommunication market, e.g. prices of the calls and text messages and the way individuals use their mobile phones. Mobile phone technology has developed very fast and people use mobile phones for much more than just calling and texting. It is quite likely that the added possibilities will change people's calling and texting habits and thus the content of data is changing too. Such change in the data will likely affect comparability over time. From the positive side, getting mobile positioning data does not cause any extra burden and the production of the statistics can be done very fast.

V. Conclusions

48. In this paper the main focus was to describe current results and methodology of passive mobile positioning and questions related this methodology. Advantages of this method over traditional methods used in border crossing statistics such as census, surveys

and counters, are better spatial and temporal resolution of data; a longer observation period, and the digital and automatic data collection. But also there are also problems in need of solutions. These problems concern legislative aspects, complete access to data, and need to develop methodology about measuring labour migration/temporary working. It is important to emphasize that pending questions would be related to both measuring mobility between countries and temporary working.

49. It is possible to bring out some further steps to move on with the process of developing. First, such segmentation needs to be properly finalised with a multi-layer analysis to consider all of these factors. Thus, from the aforementioned segmentation methods (frequency, duration, timing, geography), an algorithm could be compiled the help to identify the potential transnational commuters. Second, the result should be compared with national censuses and registers to determine the accuracy of such an algorithm of „passive“ and anonymous positioning. It is vital to emphasise that migration always has two sides – a starting point and a destination – and migration methodology needs to consider the situation, knowledge and needs of both sides. Thirdly, we should organise a survey on phone use and positioning where people are interviewed and their phone use data is retrieved to be analysed in terms of the connections between their travel behaviour and IT use.

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